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A Systematic Survey of Simulation Tools for Cloud and Mobile Cloud Computing Paradigm

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***Abstract*—Cloud computing (CC) provides fast and on-demand access to virtually unlimited computing resources. Mobile cloud computing (MCC) is a new technology that brings CC and mobile devices together. MCC allows mobile devices access to cloud services. Describe the basic architectures for various MCC applications, as well as a brief comparison of cloud and MCC. As CC becomes more common, researchers in this field may need to conduct real-world experiments in their studies. Configuring and running these experiments in real-world cloud environments is costly. As a consequence, modeling and simulation approaches are suitable solutions that can be used to simulate cloud computing environments. Several simulation tools tailored to CC have been developed. The most powerful simulation methods in this field of study are described in this article. Among them are CloudSim, CloudSim Plus, CloudAnalyst, iFogSim, and CloudReports.**

Index Terms*—*Cloud Computing, Categories of Cloud Simulators, Mobile Cloud Computing, Simulation Tools

I. INTRODUCTION

Smart devices have become more common in recent years, and they assist users in a variety of ways. Smart devices have proven useful as a result of enhanced features, providing tools that are available whenever and anywhere to meet a user's needs regardless of their location [1]. CC is an Internet-based [2] computing model [64] that distributes on-demand resources (such as networks, servers, storage, applications, and services), software, and data to multiple user devices [2]. CC is often the use of hardware and software to deliver a service over a network (typically the internet). Users can access data and use applications stored in the cloud from any device with an internet connection [3]. A Cloud Service Provider [52], such as Google's Gmail, is an example [3]. Users of CC can still [4] access [81] resources through the internet. They just have to pay for those services in proportion to how much they need them. Each resource was outsourced to the client by the cloud processing provider [4]. MCC [1] is the product of the integration of CC and mobile computing. Tablets and smartphones, among other MCC gadgets, have become an important part of our modern digital lifestyle. According to the International Data Corporation (IDC) Worldwide Quarterly Smart Connected Device Tracker, smartphone and tablet shipments have increased exponentially in recent years, surpassing 1.9 billion units in 2016 [5]. For the [6] Internet-assisted [83] provision of services to mobile cloud users, MCC has a qualitative, flexible, and cost-effective delivery system [6]. To fully use CC for mobile devices, MCC is launching new types of applications and facilities [7]. MCC has a range of positive effects that make it appealing to industry and researchers, including the computing power and battery life of [8] mobile [74] devices, meeting the services and software demands of most mobile users with low-end [8] mobile [61] devices, and maximizing resource sharing and reuse in cloud infrastructures [8]. If CC researchers need to conduct actual experiments as part of their research, the configuration, implementation, and experiments in cloud environments can be very costly. One viable choice is to use [1] models [62] and simulation tools to simulate cloud environments and conduct the required testing. CloudSim, CloudSim Plus, CloudAnalyst, CloudReports, and iFogSim [1] are some of the most powerful simulation tools for CC environments [77] that allow researchers to simulate many complex tasks [75].

A. *Why Mobile cloud computing*

- In terms of [9] energy, [84] mobile devices face numerous challenges (battery life [9], storage [9], bandwidth [9], and so on) [7].
- CC benefits customers by allowing [7] cloud [76] providers to use infrastructure, networks, and applications on-demand, at a low cost, and elastically [7].
- MCC provides mobile users with cloud [35] data [65] storage [35] and processing [86] capabilities, removing the need for a powerful computer setup [7] (for example, CPU speed [9], memory space [9], and others.) since all resource-intensive CC can be done [7].

B. *The Architecture of MCC*

MCC is a relatively new computing phenomenon, and the basic general idea behind an MCC architecture is mobile devices, mobile networks, and cloud servers [10]. Mobile [79] devices access the Internet and link to cloud servers via the Internet using a wireless network [10]. The general MCC architecture is depicted in Figure 1. This is a basic MCC architecture [10]. The review research paper is set out as follows: Section 2: Shows the background & plan of study. Section 3 shows the Features Comparison of CC and MCC. Section 4 is based on a Literature Review. Section 5 discussed the Popular Categories of Cloud Simulators. Section 6 discusses the Architecture of Various Simulators. Section 7 is based on the Discussion. Section 8 presents the Future Directions and presents Concluding Remarks.

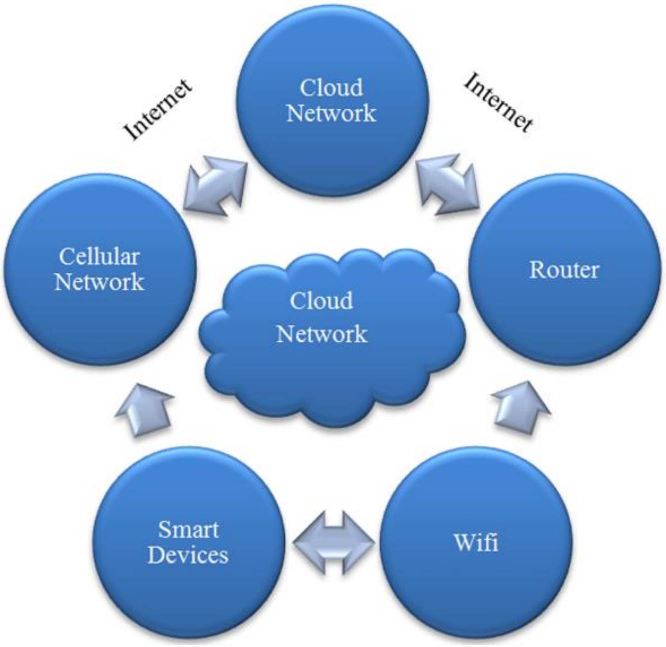

Fig. 1 Showing the Standard Architecture of MCC [10]

II. BACKGROUND AND PLAN OF STUDY

The following paragraphs clarify the study's strategy and discuss the selection of research articles discussed in the research, such as data sources and research criteria.

A. Search Standard

Through well-known work, a systematic study of simulation tools was conducted. CC, categories of cloud simulators, MCC, and simulation tools were used [88] after search string terms. This also involves the architecture of MCC, features comparison of CC and MCC & so on. The collection of search engines in this research is listed in Table 1.

TABLE I REPOSITORIES (SOURCES) USED FOR COLLECTION OF ARTICLES

Finding Engine	**Source Address**
IEEE Xplore	http://ieeexplore.ieee.org
Springer	http://springer.com
Elsevier	https://www.elsevier.com/
Semantic Scholar	http://semanticscholar.org

B. Data Sources

For the survey, several [70] different data [82] sources were chosen. As a source for the list of research papers related to them, the research article systematically searched conferences and journal research articles in Scopus, journals, Google Scholar, books, and magazines. Figure 2 shows the percentage of research papers read from multiple sources.

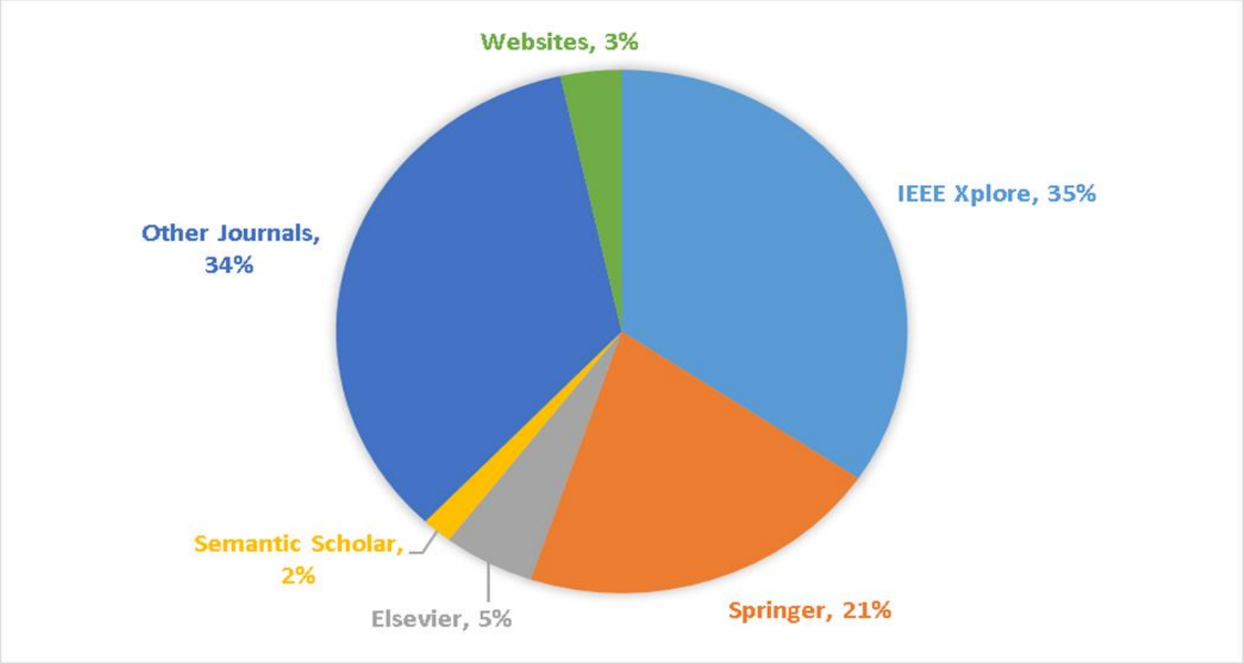

Fig. 2 Showing the percentage of research articles that are read from several sources

C. Exploration Standards

From 2015 to 2020, the study was carried out. Research papers that comply with the standard evaluation are included in the screened research articles. It contains peer-reviewed academic articles from Scopus, journals, google scholar, books, blogs, and white papers from 2015 to 2020, the number of papers read is shown in Figure 3.

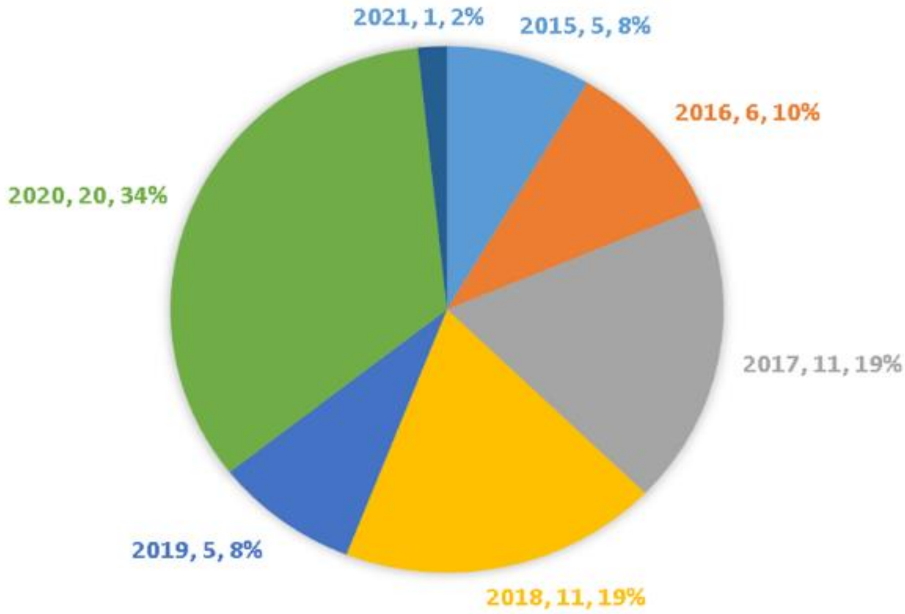

Fig. 3 Showing the number of the articles reads from 2015 to 2021

III. FEATURES COMPARISON OF CC AND MCC

Although MCC inherits CC characteristics, there are important fundamental discrepancies between the two technologies, which are summarized and presented in Table 2 [9]. CC aims to provide desktop clients with a wide range of portable technological [9] resources, [78] while MCC intends to serve mobile users and provide limitless on-the-go functionality. CC and MCC differ depending on the service provider.

CC services are made up of one or more centralized computing entities, known as cloud data centers that operate in parallel and are located on the provider's premises under corporate control. Cloud-based properties, on the other hand, can be any [9] computer [59] system that inherits cloud technologies and principles capable of mitigating mobile device resource shortages [9]. Although MCC uses both wired and wireless tools, CC relies primarily on wired communications. While wireless is the most common mode of communication in MCC, immobile cloud-based services make use of wired networks to enhance end-user [9] computing [54] experiences. The wired [9] network [80] is beneficial in areas like live VM relocation, which is an emerging trend aimed at minimizing the impact of device mobility during the augmentation process [9]

TABLE II SIGNIFICANT CLOUD COMPUTING AND MCC FEATURES COMPARISON [9]. [90]

Attributes	**CC**	**MCC**
Consumer Assistance	Desktop Users	Mobile Users
Assistance Providers	Massive Datacenters	Cloud Assets
Internet Carrier	Wired	Wired/Wireless
Objectives	Elasticity, Pay-As-You-Use	Mobile Augmentation
Energy Solutions	Save Resources, and Emit Less CO2 on the Server-Side	Conserve the Customer's Battery
Mobility	Neither the Server nor the Client	Client as well as Server
The Main Concerns of End-users	Monetary Expense of Ownership and Management of Proprietary Capital	Temporal, Electricity, and Overhead Contact

IV. LITERATURE REVIEW

N. Mansouri et al. [12] suggested that how to use CC is one of the major hurdles to assessing various cloud resource utilization designs and cloud system capacity based on QoS limitations. In this article, they describe a comparative study of 33 software for cloud environments, and to assess their efficiency, eight common simulators are evaluated realistic way, depending on distinct situations. Ultimately, it explores the open challenges for more study and future problems. Amit Sundas & Surya Narayan Panda [13] suggested that the objectives of CC are to provide net-based application services with a stable, manageable, fault-tolerant, and stable infrastructure. With the case study of one of the CloudSim simulation methods, this paper also aims to provide the significance of simulation for performing different laboratory beds. It also debated its structure, design elements, and application. Finally, the setup guides for using CloudSim in the Net Beans IDE and Eclipse are also given in this document. Sharmistha Puhan et al. [14] suggested that 'CC' is one of the innovations that have seen massive growth in recent years intending to provide computing as a service. It's not an easy job to satisfy technical needs. This paper examines current technologies designed to increase energy savings for large-scale CC infrastructures while not sacrificing the QoS and efficiency by analyzing all possible locations of cloud infrastructure that are responsible for significant energy usage. Muhammad Hassaan [15] suggested that it has become the main field of research due to the increased energy usage of CC environments. In real CC networks, the amount of energy usage becomes hard to estimate. This paper evaluates three different popular cloud energy consumption measuring simulators: CloudSim, CloudAnalyst & GreenCloud. All of these simulators can determine energy consumption according to their ability and capacity. Azlan Ismail [16] suggested that the provision of multiple applications in different fields involves a wide-scale cloud data center. Because of the massive operations and growth of cloud data centers, power demand is expected to grow. An analysis of current cloud simulation studies with multiple classifications is presented in this paper. It also provides some insights into the selected cloud simulators by emphasizing the assists for energy-driven simulation and the effects of cloud simulators on efficient work. Even this article highlights the problems of the transparent and future. Manoel C. Silva Filho et al. [17] indicated that CC is a proven technology that currently faces many obstacles to supplying on-demand computing services. Management of common resources, energy use, load balancing, provision and distribution of resources, and satisfaction of service level agreements (SLAs) are significant issues. This work highlights the advantages of CloudSim Plus, its basic characteristics, and how it guarantees greater precision, ease of extension, and ease of use. Niti Naik & Mayuri A. Mehta [18] suggested that the processing and storage power of CC is rising and hence developers and programmers are installing their data and folders on the cloud. This survey offers a detailed overview of different methods for cloud simulation, allowing researchers and developers to choose the best suitable tool for cloud simulation. It can also be used as a database of existing cloud simulators to create new designs. Andras Markus & Attila Kertesz [19] indicated that recent advancements in information and communication technologies have had a huge effect on distributed networks over the past 10 years by developing concepts like CC, Fog Computing, and the Internet of Things (IoT). The key contribution of this analysis is innovative classification perspectives like software efficiency, which is implemented by examining the code of the simulators being considered. Finally, the related results of our classifications are discussed and open questions that require more study are highlighted. G. Anusooya et al. [20] suggested that the data center be a very important component of CC, which includes numerous types of databases that hold and operate all kinds of information. The Network, Server, etc. data center consumes more energy, more power & more carbon emissions. Multiple strategies and algorithms are described in this study to decrease the cloud's resources & power usage. J.M.Nandhini & T.Gnanasekaran [21] indicated that CC is a broad collection of internet-accessible computational tools. CC provides services with optimum efficiency and resource utilization to achieve flexibility, scalability, and economic subscale. This paper discusses the study of different cloud simulators with a focus on the use of cloud simulators. Elena N. Desyatirikova & Almothana Khodar [22] suggested that CC is indicated to be fairly distributed computing with heterogeneous computational resources. Resource sharing, resource convenience that meets the needs, and many cloud-facing box-management problems are addressed. The evaluation and comparison of different current service broker algorithms and load equalizing algorithms in CC in this paper. Mohammad Irfan Bala & Mohammad Ahsan Chishti [23] it was suggested that with the launch of IoT, information and communication technology has undergone unparalleled modifications and the implementation of IoT applications depends primarily on cloud resources such as computation, storage, and networking, respectively. Fog computing was implemented as a supplement to the cloud infrastructure since IoT system requirements would surpass the cloud resources shortly. Dongjoo Seo [24] it was suggested that Dynamic Internet of Things (IoT) applications like Healthcare IoT contain a variety of kernel intensities of computation, data, and communication and have various QoS specification intolerances, like latency, throughput, availability, accuracy, respectively. A detailed instrument to conduct an effective full-stack evaluation is needed to ensure QoS specifications for the apps. First, in this paper, they suggest a full-stack structure for co-simulating communication and computing dimensions of an IoT system in a complex scenario. Taskeen Zaidi [25] indicated that the cloud-computing methodology offers customer services worldwide. Because of the need for efficiency of asset use and energy usage, the large-scale data center structure is very complicated. Via GUI representations, simulation tools provide a simple way to model complicated research issues. The simulation scenario for different VM and resource use and simulation environments for a supplier, consumer, SAN, and network output respectively. Fairouz Fakhfakh et al. [26] suggested that CC has become a successful model aimed at offering on-demand computing tools and services. The adoption of these programs has been growing rapidly. This review article provides a survey of CC's current simulation methods. It also offers a basic and comparative study of the instruments examined. Finally, for further analysis, a big problem to be tackled stands out.

TABLE III A Summary of the Literature on Simulation Tools for Efficient Cloud Computing Paradigm

Ref	**Name**	**Year**	**Advantages & Disadvantages of the Research**	
[12]	N. Mansouri et al.	2020	• A comparison of 33 cloud environment resources is given. • Makes suggestions for researchers on how to use the most appropriate tool.	• In the cloud, there is a lack of protection. • It is not easy to use and customize. • The new simulators' scalability is insufficient. • Support for Distributed Execution Tools is lacking.
[13]	Amit Sundas and Surya Narayan Panda	2020	Allows for the simulation of multiple duplications occurring at the same time.	• Inadequate SLA management. • Inability to automatically scale vertical virtual machines.
[14]	Sharmistha Puhan et al.	2020	• Offers effective energy schemes. • Reducing resource consumption and improving QoS.	The Data Center's response time does not increase with fewer computers, and higher frequency memory configurations use more resources.
[15]	Muhammad Hassaan	2020	• Provides various power-saving algorithms and explanations of packet-level capture. • Consumption of resources according to their abilities and capacity.	Lack of small data center activities.
[16]	Azlan Ismail	2020	Supports simulations that are based on energy.	In cloud simulation, there is a lack of a holistic viewpoint.
[17]	Manoel C. Silva Filho et al.	2017	Maintainability, reusability, extensibility, and precision are all factors to consider.	• Inadequate SLA management. • Inability to automatically scale vertical virtual machines.
[18]	Niti Naik and Mayuri A. Mehta	2018	Provides a list of cloud simulators to help researchers and developers choose the most appropriate tool for cloud simulation.	The user must be familiar with the C++/Java programming language to use the simulator.
[19]	Andras Markus and Attila Kertesz	2020	• The network's simple architecture. • Abstraction is at a lower level.	• Lack of cost modeling. • The energy awareness is out of reach.
[20]	G. Anusooya et al.	2020	It provides cloud energy and power savings as well as workload control in data centers.	In the simulation, there is a lack of accuracy and efficiency.
[21]	J.M.Nandhini and T.Gnanasekaran	2019	Help in calculating costs and determining how assets are used.	Inadequate storage issues and VM failures of varying abilities.
[22]	Elena N. Desyatirikova and Almothana Khodar	2019	• Providing the best possible answer time. • Increasing the productivity of distribution centers.	• The data center's existing load is insufficient. • Bandwidth is scarce.
[23]	Mohammad Irfan Bala and Mohammad Ahsan Chishti	2020	The application modules are distributed between Fog devices and cloud data centers, allowing for efficient use of Cloud-Fog resources.	The need for further advances in load balancing algorithms.
[24]	Dongjoo Seo et al.	2020	The controller module is incorporated into the system and can configure any layer during runtime.	Lack of reliability.
[25]	Taskeen Zaidi	2020	Data centers would make good use of their power.	Validation of cloud technology is incomplete.
[26]	Fairouz Fakhfakh et al.	2017	Providing applications with a complex model.	The constraint of time.

V. MOST COMMON CATEGORIES OF CLOUD SIMULATORS

The most common types of [11] cloud [69] simulators are discussed in this section. There are two types of cloud simulators: (1) general cloud simulators and (2) provisioning data center simulators. CloudSim, CloudSim Plus, Cloud Analyst, and iFogSim are some of the most common cloud simulators. With CloudReports simulator, Provisioning Data Center has Energy-Aware Provisioning. Figure 4 depicts the most popular cloud simulator categories [11].

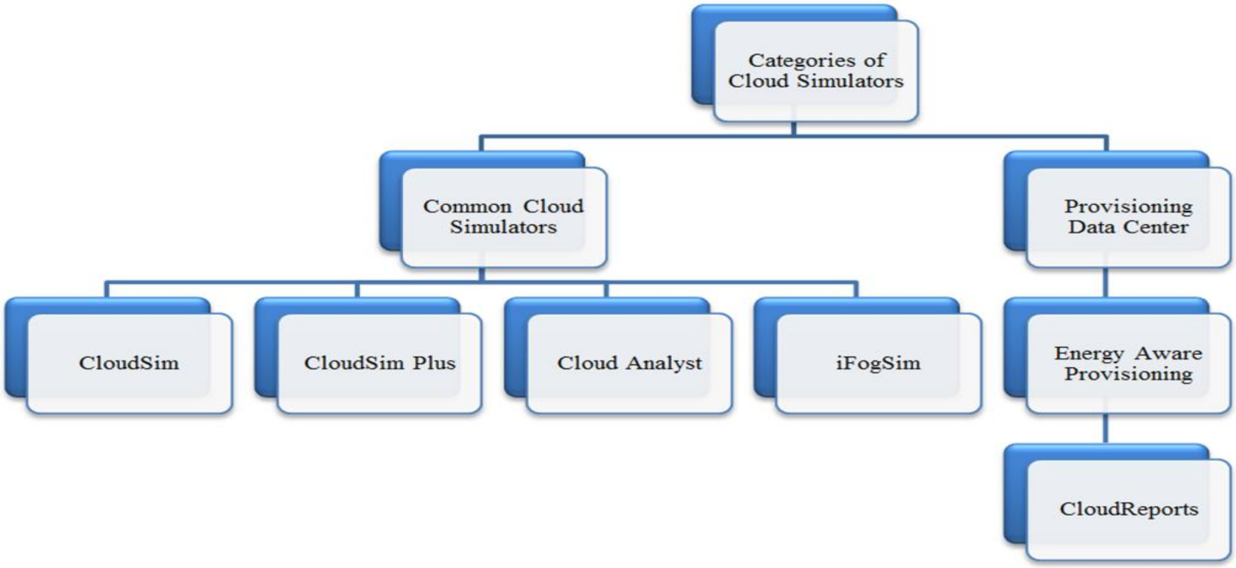

Fig. 4 Showing the Categories of Cloud Simulators [11]

A. *Common Cloud Simulators*

While some simulators model many of the Cloud's complexities simplistically and abstractly, these tools are often easy to extend and use. Following that, only the characteristics that are of interest are extended, while the contradictory characteristics are ignored. This category encompasses the tools listed in this section [11].

1) CloudSim: N. Mansouri et al. [12] proposed CloudSim as a toolkit for modeling cloud environments at the University of Melborn's CLOUD Laboratory. CloudSim simulates data centers, virtual servers, service brokers, and resource provisioning methods. It provides a flexible switch between space-shared and time-shared resource allocations to processing components. Researchers can quickly and easily deploy the cloud-based app in a variety of environments and test the performance. Amit Sundas and Surya Narayan Panda [13] suggested that the CloudSim provides simulation, smooth modeling, and practical design in the sense of CC. It's a place where service brokers, data centers, broad-scale allocation policies, scheduling, and other items are discussed. It has some advanced features, such as a virtualization engine, to design the implementation and monitoring of the life-cycle of this device in the data center. The GridSim architecture, which was created in the lab for power systems, serves as the foundation for CloudSim's infrastructure. Sharmistha Puhan et al. [14] suggested that the modeling of the infrastructure as a service sheet, according to data centers can be represented in CloudSim. CloudSim can be used to create various models to illustrate energy usage in cloud environments. You can simulate VMS migration, host machine termination, and so on. When it comes to designing energy models, there are a few things to bear in mind. Muhammad Hassaan [15] suggested that the simulation framework for CloudSim is a Java-based simulation toolkit that can design extremely large-scale clouds and support communication among cloud system components. It's an event-based simulator. It has a specific function called federated strategy. A federated cloud is a series of internal and externally hosted cloud resources that are distributed to meet business needs. Azlan Ismail [16] discusses the environment for virtualization and multi-tenant infrastructure. The CloudSim is a true testbed (for example, Amazon EC2) that is limited in the scaling and replication of test results, which inspired CloudSim's architecture. As a result, CloudSim provides a simplified and extensible simulation framework that includes modeling, simulation, and testing, especially for large-scale cloud data centers. It generates a cost-free, repeatable, and manageable environment and fine-tunes the success bottlenecks before deploying on real clouds.

*2) CloudSim Plus:*Manoel C. Silva Filho et al. [17] suggested that the CloudSim Plus is a Java 8 simulation framework that allows different CC services to be modeled and simulated, from IaaS to SaaS levels. It facilitates the implementation of simulation scenarios for algorithm testing, evaluation, and validation for a variety of goals. CloudSim Plus facilitates the simulation of entire CC systems, leaving interested developers with only the challenge of adding specific new features to test, try, and evaluate. Niti Naik and Mayuri A.

Mehta [18] suggested that the CloudSim Plus, is free software, an object-oriented simulation program. As a CloudSim extension, CloudSim Plus is developed. The CloudSim Plus API is the main component that represents the simulation framework API. Cloud simulation studies must be permitted to take place. [19] Andras Markus and Attila Kertesz CloudSim Plus, it was proposed, is a revised and renamed version of CloudSim that aims to make simulation easier to use and more accurate. Often available on GitHub.

3) Cloud Analyst: G. Anusooya et al. [20] suggested using the CloudAnalyst simulation method to verify overall response time by comparing the performance of different algorithms. The CloudAnalyst tool appears to be straightforward, with a graphical environment that appears to be easy to use. Users can more quickly and easily perceive results thanks to the visual result. The CloudAnalyst has the following features: (1) it is simple to use. (2) The distinguishing simulation features, include a large configuration point and versatility. (3) Graphics-based outcome. (4) Tests must be replicated, and (5) the output must be processed. J.M.Nandhini & T.Gnanasekaran [21] suggested the cloud analyst features like: (1) Incorporates cloud application analytics units into CloudSim. (2) In a large-scale cloud environment, geographically distributed computer servers and client workloads for simulation assessment (3) Service brokers improve the productivity of software and service providers. The key units are the data center, application, server broker, host, virtual machine, and cloud coordinator. Elena N. Desyatirikova & Almothana Khodar [22] suggested that the Cloud Analyst will consist of a set of elements that will serve as the foundation for CC, such as VMS, Cloudlets (Jobs and User Requests), Data Centers, Service Brokers, and Hosts.

4) iFogSim: Mohammad Irfan Bala & Mohammad Ahsan Chishti [23] suggested that the iFogSim is a widely used Fog Computing simulator. iFogSim has been developed, and it includes all of the CloudSim elements and features. iFogSim has received a lot of help from the research community, and it can recognize various performance parameters such as energy consumption, latency, response time, cost, and so on. It also allows for the replication of experiments in a controlled environment. It operates based on a stream processing model, in which sensors continuously generate data that fog devices analyze, enabling people to quickly assess the results of various placement algorithms. Dongjoo Seo [24] suggested that iFogSim is one of CloudSim-based most common simulators. iFogSim can model IoT and fog conditions to measure latency, network congestion, and system energy consumption. However, a simpler approach to modeling latency workload is used. iFogSim can simulate three-layer IoT-fog systems using various configurations. Although the simulator is used to evaluate several works, it fails to accurately model the computation schedule while processing objects. The more realistic simulation necessitates the creation of a computer model. It is well known that multi-core CPU performance does not increase linearly due to interactions between system components.

B. *Energy-Aware Provisioning*

The energy supply is one of the most critical for the supplier because it can result in considerable savings. Initially, energy [11] efficiency [71] can be achieved at both the network interface and host level. The Processor fee is the most common parameter for estimating energy consumption. More sophisticated simulators require air-conditioning since this is a [11] major [66] contributor to the energy bill. The following simulators focus on energy consumption modeling [11].

1) CloudReports: Taskeen Zaidi [25] suggested that the Cloud reports are a powerful and versatile simulation tool for computing data center and resource energy through a graphical user interface (GUI) in a CC environment; it produces reports and organizes simulation results using high-level data. This provides an API for creating extensions using Java reflection and APIs. Clients, data centers, physical computers, virtual machines, network, and network area space, and other central enterprises are included in the cloud study. These organizations partner with the simulation administrator to manage a simulation environment. Fairouz Fakhfakh et al. [26] suggested that it adds many improvements to CloudSim's architecture. It introduces a graphical user interface (GUI) with a range of options. For starters, it allows several simulations to run at the same time. It can also generate reports with comprehensive information and export simulation data. This information is related to the cost of using utilities, energy use, and execution time, among other things.

VI. THE ARCHITECTURE OF VARIOUS SIMULATORS

In this section, the architecture of cloud simulators is introduced.

A. *CloudSim Architecture*

CloudSim proposed in 2009 [46]. CloudSim's multifaceted [27] software [67] framework scheme and structural components are shown in Figure 5. The CloudSim simulation layer enables the development and simulation of virtual computers, memory, storage, and bandwidth in virtualized cloud-based [27] data center [38] environments with specific organizational boundaries. Stipulating hosts to VMs, monitoring request execution, and observing robust process states are just a few of the critical issues that run through this layer. It also simulates transmissions and extends the workload on a cloud infrastructure. The layer cost for space and memory use is won [27]. There is no GUI [41] and it has a small prototype declaration that does not finance TCP / IP [27]. During the simulation era, the CloudSim layer handles the initialization and operation of main identities (virtual machines, hosts, data centers, applications) [47]. Many library functions written in the Java programming language are included in CloudSim [49].

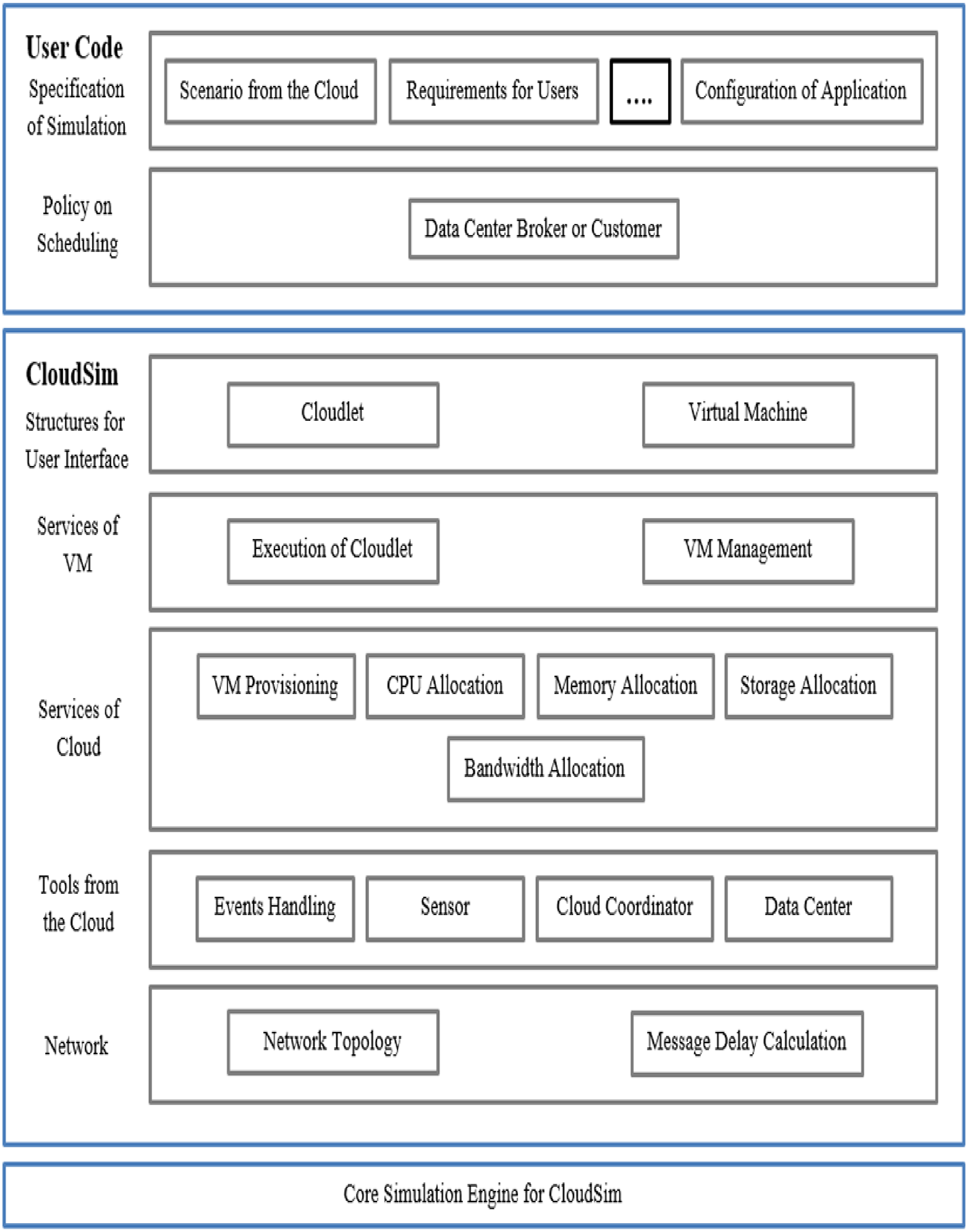

Fig. 5 Showing the Architecture of CloudSim [28], [43]

B. CloudSim Plus Architecture

CloudSim Plus is made up of a variety of [17] different pieces [89]. The CloudSim Plus API is the main component that represents the simulation framework API. It is the only module that is needed to run cloud simulation experiments [17]. CloudSim Plus is an extensible simulation framework for modeling and simulation of [50] CC [55] infrastructures and facilities [50].

Figure 6 depicts a condensed outline of the package structure. CloudSim Plus's exclusive feature is included in packages with a brighter hue. Those lightweight ones were introduced primarily to [17] improve [87] coordination and separation of issues, but the class in question was completely redesigned and refactored.

The following are the most popular CloudSim Plus packages and the groups they contain [17]:

- **Distributions:** Groups that generate pseudo-random numbers using the simulation API's [17] several [72] statistical distributions. They can also be used by developers when building simulations [17].
- **Network:** Network simulations are made possible by classes for building internet infrastructure for data centers [17].
- **Power:** Groups that allow power-aware simulations, i.e., energy-usage models that can be extended by developers developing simulations [17].

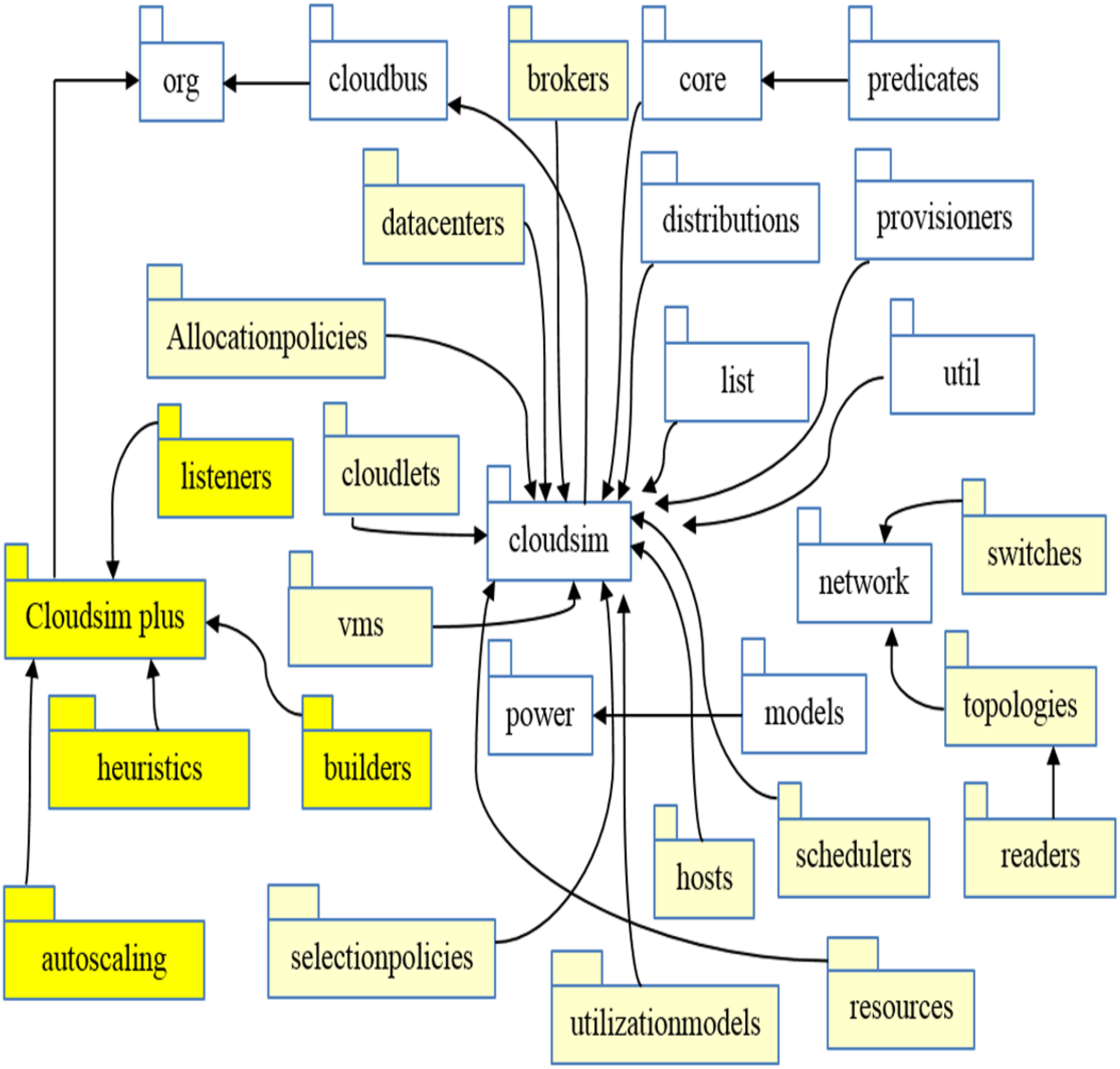

Fig. 6 Showing the CloudSim Plus API Package Kit [17]

C. *CloudAnalyst Architecture*

Figure 7 depicts the CloudAnalyst Architecture. CloudAnalyst provides a [29] user-friendly GUI [40] for managing any geographically distributed system, such as application workload description, traffic, data center location, number of customers per data center, and data center resources.

CloudAnalyst can generate output in the form of a map or table that summarizes the massive number of users and system stats during the simulation time [29]. It distinguishes between the programming world and the simulation environment [48].

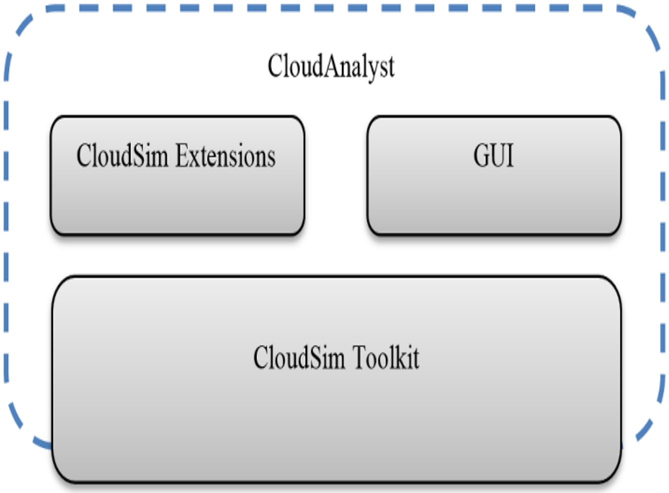

Fig. 7 Showing the CloudAnalyst Architecture [30], [45]

D. *iFogSim Architecture*

The iFogSim structure is made up of several components: (1) The iFogSim simulator has been expanded; (2) the Sniper Multi-Core simulator has been added; (3) the System Cross-layer Controller has been added; and (4) an environment co-simulation module has been added (see Figure 8). The simulation starts with settings for the loading system and application codes in the Module Cosimulation Environment.

The virtual computer's hardware, network layer, and simulation system specifications are all part of the machine settings. Furthermore, the target programs that should be run on [24] virtual [63] machines are program codes [24]. The Sniper simulator first runs the loaded app codes on the required device hardware configuration to generate statistics for subsequent moves.

The iFogSim then uses the stats to simulate the system and network layer according to the device specifications. At each epoch, the Device Cross-layer Controller updates the system configurations according to the user-defined law. In other words, the controller can influence QoS by changing the hardware or platform specifications. For the system configuration specified [24], the Framework records the application's execution time and energy consumption.

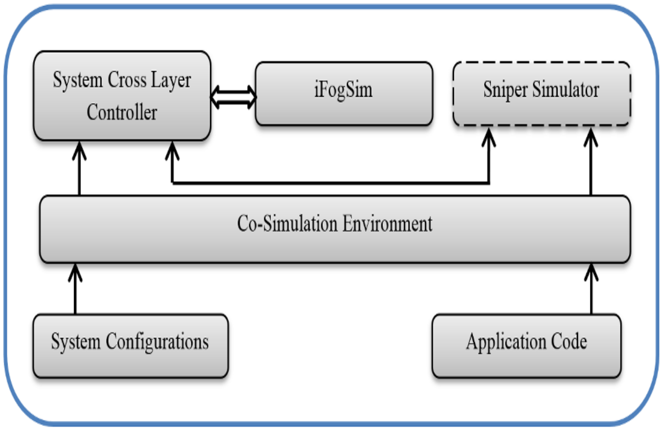

Fig. 8 Showing the iFogSim Architecture [24]

E. *CloudReports Architecture*

It is an expandable simulation software [58] for energy-aware [32] cloud computing [56], and [57] environments that allow researchers to design a variety of complex concepts through an interface. It has four layers on top of the [32] CloudSim simulation engine [37]: Reports Manager, Simulation Manager, Extensions, and Core Entities are the first four items on the list. CloudReports' main advantage is its modular architecture, which allows its API to be extended to test new scheduling and provisioning [31] algorithms [60], [73]. CloudReports is based on the event-oriented simulation mechanism and supports modeling for limited power consumption. High accuracy and adaptive [32] simulations [53] based on support for auto-VM migration are two of CloudReports' key features. It includes the Java Reflection API for creating plug-in extensions that are allowed [32]. It features a graphical user interface with a variety of features [42]. Figure 9 depicts the CloudReports Architecture.

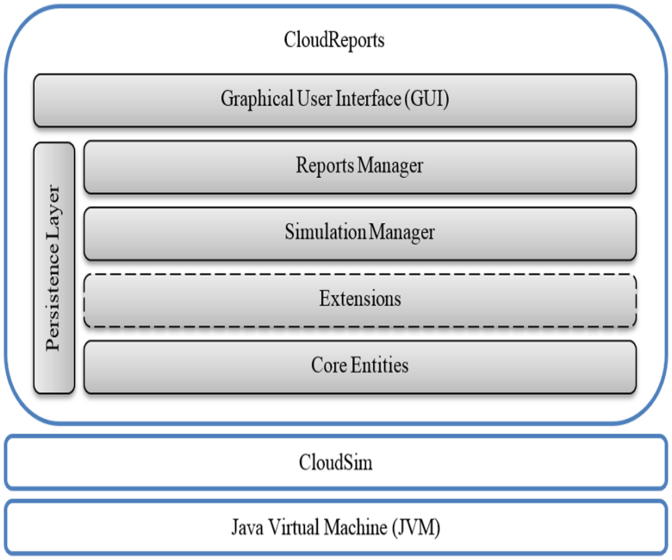

Fig. 9 Showing the CloudReports Architecture [1]

VII. DISCUSSION

Table 4 summarizes the main cloud simulation models presented in this section (CloudSim, CloudSim Plus, CloudAnalyst, iFogSim, and CloudReports) for [33] various [68] parameters [85] such as (simulator type, simulation time [33], availability [51], hardware/software associate, programming language, basic policy, repetition of analysis, GUI, user expectations, dynamic run) and the level of simulation support [33].

TABLE IV SELECTION OF CLOUD SIMULATORS A SIMULATION-BASED ASSESSMENT OF THE SPECIFICATIONS [33], [34], [36], [39], [44]

Kind of Simulator	Side by Side Analysis	Time of Simulation	Availability	Hdwe/Soft Associate	Programing Language	Fundamental Policy	Analysis Repetition	GUI	User Preferences	Dynamic Run	Simulator	Cost
Event-Based	✗	Second	✓	Software	Java	SimJava	✓	✗	✓	✓	CloudSim	Free
Event-Based	✗	Second	✓	Software	Java	SimJava	✓	✗	✓	✓	CloudSim Plus	Free
Event-Based	✗	Second	✓	Software	Java	CloudSim/SimJava	✓	✓	✓	✓	CloudAnalyst	Free
Event-Based	✗	Second	✓	Software	Java	CloudSim/SimJava	✓	✓	✓	✓	iFogSim	Free
Event-Based	✗	Second	✗	Software	Java	CloudSim	✓	✓	✓	✓	CloudReport	Free

VIII. CONCLUSION AND FUTURE WORK

The ever-changing nature of computing systems simulation software is becoming an increasingly common and difficult choice for designing, installing, monitoring, and assessing the performance of a device. Cost and reliability trade-offs in pay-as-you-go (PAYG) environments have been evaluated using CC simulators. This research was able to compile a list of simulation tools that are suitable for cloud architectures. CloudSim, CloudSim Plus, CloudAnalyst, iFogSim, and CloudReport are among the resources discussed. Table 4 is showing that CloudAnalyst is the better tool for simulation. It provides users with full GUI assistance and operates on Java virtual machines. Furthermore, it was created with cloud simulation in mind. The cloud analyst simulation-based approach has quickly gained popularity as a tool for evaluating and analyzing CC systems. Expanding the cloud analyst tool's capabilities to match modern algorithms and improving the interface is another area of study. The expansion of the simulation module to include graphics simulation has potential.

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